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An Aerospace and Defense Industry Market Index for 1950–2012 and the Connection With Defense Spending

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14. ABSTRACT

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Preface & Acknowledgements

Welcome to our Ninth Annual Acquisition Research Symposium! This event is the highlight of the year for the Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) because it showcases the findings of recently completed research projects—and that research activity has been prolific! Since the ARP's founding in 2003, over 800 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 60 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a "broker" to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and hope this symposium will spark even more participation.

We encourage you to be active participants at the symposium. Indeed, active participation has been the hallmark of previous symposia. We purposely limit attendance to 350 people to encourage just that. In addition, this forum is unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. Seldom will you get the opportunity to interact with so many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. In the words of one senior government official, "I would not miss this symposium for the world as it is the best forum I've found for catching up on acquisition issues and learning from the great presenters."

We expect affordability to be a major focus at this year's event. It is a central tenet of the DoD's Better Buying Power initiatives, and budget projections indicate it will continue to be important as the nation works its way out of the recession. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you're a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

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We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this symposium.

James B. Greene Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

Panel 8. Assessing Defense Industry Health in a Constrained Fiscal and Global Context

Wednesday, May 16, 2012	
1:45 p.m. – 3:15 p.m.	**Chair: James E. Thomsen,** Principal Civilian Deputy, Assistant Secretary of the Navy (Research, Development, and Acquisition)
	An Aerospace and Defense Industry Market Index for 1950–2012 and the Connection With Defense Spending
	Robert Bruce Williamson, *National Defense Business Institute, University of Tennessee*
	The Impact of Macroeconomic Forces and Changing Trade Winds on the Global Defense Industrial Base
	Nayantara Hensel, *National Defense University*
	Global Aerospace Industries: Rapid Changes Ahead? (Abridged)
	Raymond Franck and Ira Lewis, *Naval Postgraduate School* Bernard Udis, *University of Colorado at Boulder*

James E. Thomsen—Mr. Thomsen is currently the principal civilian deputy assistant secretary (RD&A). His responsibilities include leadership of the acquisition workforce and systems engineering. Previously, Thomsen served as the program executive officer for littoral and mine warfare (PEO LMW). As PEO LMW, he had life cycle responsibility to design, produce, field, and support warfighting capability for the littoral battle space and for the global war on terrorism. Mr. Thomsen led seven program offices that comprised 224 programs ranging from ACAT I through ACAT IV and included several developmental programs that addressed urgent warfighting needs for Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). In 2003, Mr. Thomsen was selected as the executive director for the Program Executive Office, Littoral and Mine Warfare, where he executed the Navy's material acquisition programs for integrated undersea surveillance, naval EOD/JCREW, naval special warfare, mine warfare surface and aviation, unmanned maritime vehicles, naval anti-terrorism/force protection ashore and afloat, and LCS Mission Modules for anti-submarine warfare (ASW), Mine Warfare, and anti-surface warfare (ASUW).

Prior to this position, Mr. Thomsen was assigned as head of the Naval Sea Systems Command (NAVSEA) Dahlgren Division's Weapons Systems Department, directing over 550 scientists, engineers, and technicians and advancing key technical achievements in naval surface weapons systems. Mr. Thomsen was selected as a member of the Senior Executive Service (SES) in November 1998 and then named as head of the Coastal Warfare Systems Department, directing all of the littoral warfare research, development, test, and evaluation (RDT&E) programs at the Naval Surface Warfare Center (Panama City), which included 360 scientists, engineers, technicians, and military personnel.

Prior to November 1998, Mr. Thomsen served as program manager for mine warfare programs, for which he was awarded the National Defense Industrial Association (NDIA) Bronze Medal for his achievements in mine warfare; senior systems engineer for the Shallow Water Mine Countermeasures program; project manager for the ACAT 1D Joint US/UK Surface Ship Torpedo Defense (SSTD) program, for which he received the Commanding Officer/Technical Director Award for special achievement in technical management; and head of the Torpedo Defense Systems Development Branch and served as the system integration agent in submarine torpedo defense countermeasure programs for PMS 415.

In the early years of his 27-year career, Mr. Thomsen held engineering positions including design engineer, test engineer, project engineer, and systems engineer for several undersea warfare programs at Carderock, Panama City, and NAVSEA headquarters.

Mr. Thomsen received his bachelor's degree in ocean engineering from Florida Atlantic University in 1981 and his Master of Science degree from Florida State University in 1986.

An Aerospace and Defense Industry Market Index for 1950–2012 and the Connection With Defense Spending

Robert Bruce Williamson—Dr. Williamson is senior defense economist with the National Defense Business Institute at the University of Tennessee. Dr. Williamson provides NDBI with skills in program management, research design, economics, econometrics, and complex business modeling. He has 35 years of professional experience in managing quantitative business and public policy research, much of that in international market valuations and mergers and acquisitions. Dr. Williamson holds a BA from Cornell University in American foreign policy, an MA in international relations from the University of Denver's School of International Studies, and a PhD in industrial organization and resource economics from the University of New Mexico. [rbwilliamson@utk.edu]

Abstract

The U.S. aerospace and defense industry (ADI) is largely dependent on its U.S. government defense customer. Because of the vital yet specialized nature of that market, the health of the ADI should be assessed periodically to enable government and industry leaders to understand clearly how and to what extent changes to its capacities and capabilities can be forecast and incorporated in their policy deliberations for better decisions. It is widely assumed that changes in defense spending will affect ADI market health, but in fact, our research indicates that although true for four decades after 1950, the comfortable predictive connection between ADI equity valuations and defense spending underwent changes with the shift in ADI industry structure for the largest companies in the 1990s, and can challenge interpretation even at present. The role of large company order backlogs appears to significantly mediate the modern predictive relationship. The analysis used the ADI market health indexes by NDBI, indexes which are based on a representative industry sample of 97 companies divided by assets sizes for the entire 1950–2012 interval. The breadth and depth of the sample helps with interpretation of past and recent performance and in continuing model and predictive work.

Introduction

The U.S. aerospace and defense industry (ADI) is a national security asset uniquely structured around the needs of its U.S. government customer. The health of the ADI should be assessed regularly to enable government and industry leaders to understand fully how and to what extent changes to its capacities and capabilities can be forecast and thus included in their policy deliberations. To that end, the health of the ADI is usually considered from two complementary perspectives, that of *market* health in equity valuations for publicly traded defense companies, and secondly, that of *financial* health, measured by metrics or ratios such as profitability, operating margins, working capital, inventory, interest coverage, return on assets, and return on equity.[1] Of the two approaches, *market* health is the easiest to explain because for a group of publicly traded companies, it is possible to fashion an index from their equity market valuations and compare how their valuations have fared relative to broader stock market indexes for other industry sectors. For the most part, we will be concerned largely with the ADI's market health in the present analysis.

Investment and economic theory agree that a publicly traded company's equity will be valued for investment potential based on these measures of the company's market performance and the investor's own risk preferences in the context of other competing investments. Thus it is quite reasonable to assume that if the ADI's largest—or sole—customer increases its defense spending on existing and new programs and forces, that

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[1] Due to the complexity involved in selecting and evaluating the many dozen possible financial ratios that can be constructed from corporate financial reports, *financial* health studies for the ADI are seen less often, typically select a very small number of metrics as paramount, and seldom consider a time period longer than a decade.

these revenues will flow through the ADI companies and be reflected eventually in their financial performance and their equity valuations, as investors "price in" better times ahead.

Of course, every relationship has its wrinkles, and that between the ADI and its government customer is no exception. In their 65-year-long quixotic relationship with the defense industrial base, the Department of Defense (DoD) and National Security Space buyers have sought the grail of affordability in having "just enough" suppliers to encourage healthy price competition, without having overcapacity. The problem is that turning up or turning off production and development assets and labor force according to the swings in defense spending is *sticky*, to use the sophisticated economics term, because there are inefficiencies and real costs in buildup as well as build down.

Specifically, overcapacity during downturns creates higher costs, ties up working capital, diminishes whatever pricing power the suppliers might have as they compete for survival and a share of a shrinking pie, and dims the chance of revenue growth and future returns to expectant shareholders in equity markets. Defense spending increases, in contrast, should improve operating margins, employ unused capacity, and create some degree of pricing power with the government buyer. Equity markets should efficiently price all this information on swings in defense spending into their valuations of current and future ADI equity prices.

This is the basis for the standard assumption that significant spending on defense materials and services by the ADI's largest customer should be reflected in the market valuations of the most significant suppliers of defense products and their subcontractors and suppliers as well. Our working hypothesis is that defense spending is a predictor of the equity valuations of the major defense companies. Greater defense spending should increase the ADI market indexes because the ADI companies are developing, producing, and supporting more things the DoD needs. Conversely, reduced defense budgets should eventually show up in reduced ADI market indexes as a sign of reduced market health. But is this the case? And if not, why not?

The following section will very briefly review the practice of market and financial health studies of the defense industrial base, and introduce the ADI Index of the National Defense Business Institute. The Analysis of the Data section examines the connection between U.S. defense spending and how that is reflected in ADI market health in a graphical analysis. The Structural Modeling section presents a pair of structural regression models for the ADI Indexes and identifies significant predictors. The Discussion section offers a discussion of the findings, and the Conclusion section concludes the research.

Previous Studies

Monitoring the health of the U.S. aerospace and defense industry emerged from Cold War concerns and the post-WWII resolve not to be caught unprepared yet again for the next armed conflict.[2] The DoD was given responsibility to consider the industrial context of its acquisition decisions in 1950,[3] yet most of the monitoring by the DoD arises from the

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[2] This concern had been a central issue for President Truman and his Cabinet, who were concerned that mobilization would take too long in the modern era of war with nuclear weapons. Although no one wanted a repeat of the unpreparedness that had marked U.S. involvement in both World Wars, the larger defense suppliers were more cautious about how government planning would be re-inserted in their post-war production plans (Mrozek, 1974, p. 76 et seq.). Those circumstances before and during the Korean War began the modern quixotic relationship between the U.S. military, its civilian leadership, and the defense industrial base.

[3] Part of the motivation for the DoD's periodic reviews of the health of the defense industrial base comes from requirements first set out in the Defense Production Act of 1950. The Secretary of Defense was directed by that act to take the necessary steps to ensure the existence of a viable defense industrial base (DeLauer, 1981, p. 25).

necessity of evaluating a contractor's financial stability required to complete contracted tasks (Borah, 1995). This due diligence focus can include the review of corporate bond ratings, the use of discriminant or regression models to predict the rare likelihood of bankruptcy or contract default, and so on (Borah, 1995; Candreva,1996). From time to time, the Defense Department is nudged by Congress to review profit policies when there have been concerns that profit rates are either too high or too low relative to some industry benchmarks.[4] These studies typically encompass only the few years leading up to the study date, look at a select few financial measures, and by their infrequent production, have limited value in supporting the Defense Department's knowledge refresh on the health of the industrial base.

Defense analysts take up the same data in an effort to shed light on the very real, long-term problem of a diminishing defense industrial base. Weakened market and financial health leads to exits of defense firms or their consolidation, with the net result that there is a smaller, and potentially less competitive defense industrial base with the loss of each company.[5] Equity valuations sooner or later reflected significant program wins and losses for Republic, Douglas, Lockheed, Grumman, McDonnell Douglas, Rockwell, Northrop, and many others, and eventually, those companies were folded into the fewer, but larger companies today, all before the mid-1990s.

The quantitative empirical basis for all defense industry analysts inside and outside the Defense Department ultimately relies on metrics from industry. For publicly traded defense companies, stock market valuations and corporate financial filings are combined to create many dozen financial and market performance ratios and measures—profit rates, earnings per share, and so on. Not all suppliers to the DoD can be tracked or incorporated into a market health index. Little can be done on privately held companies who are not required to release their financial information. The smallest of publicly traded companies pose their own challenge to researchers in thinly traded stock with no price change and dispositions of closely held stock, and in the words of one observer, the corporate lifespan of a mayfly.

The market health of the defense industry is tracked by four providers, including the Aviation Week and Space Technology (AWST) Aerospace 25, the Standard & Poors 500 (S&P500) defense subset of companies,[6] the SPADE index linked to the Powershares ETF, Aerospace and Defense Portfolio,[7] the market index produced by the Center for Strategic and International Studies (CSIS),[8] and the NDBI ADI Index.

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[4] Two prominent examples are Department of Defense (1976), *Profit '76: Report of the Profit Study Group*, and the Department of Defense (1985), *Defense Financial and Investment Review*.

[5] Some research at the Naval Postgraduate School in the 1990s focused on the defense mergers altering the industry, including studies by Gursoy (1994), White (1994), Moses (1995), and Zegley (1997).

[6] In practice, the aerospace industry subgroup in the S&P500 has depended on a varying sample since its inception—not just in the specific companies included, which is to be expected, but in the number of companies said to represent the aerospace industry. In some years (1950s) there were fewer than eight companies in their aerospace and defense industry segment. This was driven by overall S&P500 sample considerations, but it has to be kept in mind in comparisons. As with any empirical method, we know sample size can matter for representativeness as well as consistency and reliability of measures.

[7] Further information is available at http:// www.spadeindex.com/aboutspadedefense.php. The SPADE index supports the DXS (NYSE:DSX) series, and is traded as the Powershares Aerospace and Defense Portfolio ETF (NYSE:PPA). The series is available 1997–2011 only, and has included about 58 companies in total during that interval. It is actively managed to inform the portfolio of the Powershares PPA ETF's management team.

[8] The CSIS Defense Index is a sample of about 23 companies currently that is managed by the Defense Industry Group at CSIS. The Index extends back to 1987, and is used in the CSIS analyses of defense industry performance. Further information is available at http://csis.org/.

All are of the market capitalization (also known as *share weighted*) type of index that avoids the problems of a Dow-like price index. *Market capitalization* or *share weighting* refers to the normalization that is based on the total value of all shares outstanding for a company. This makes for fairer comparison of large and small companies when mixed in the same index: each firm's closing stock price is multiplied by the number of equity shares outstanding, and this product for each company in the index is followed over time, updated with each change in the company's stock price, but also when a company increases or decreases the shares outstanding of its stock. The consequence for a stock market health metric is that the tracking of larger and smaller companies is considerably less volatile and trends more reliably uncovered.

The present study focuses on the NDBI Aerospace and Defense Industry Index (ADI). The ADI reflects 97 companies (65 currently) from January 1950 to the present.[9] An overview of the ADI company sample is presented in Table 1 and summarizes the current market capitalization distinctions among small, mid, and large cap companies in the ADI Index. A major factor that motivated NDBI's development of the ADI sample was the fact that studies of very important industrial policy issues seldom considered a timeframe for analysis longer than a budget cycle. In fact, there have been four major and one minor budget cycles since 1950—each with lessons to be learned.[10] With an index of sufficient length and company coverage it would be possible to better understand and interpret

- the quantitative relationship between the equity market and defense outlays;
- innovation, technology change, and industry evolution;
- effects of conflicts, political shifts, budget cycles, and economic cycles;
- the continuing pattern of industrial concentration and the impact on affordability; and
- financial health measurement issues and opportunities.

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[9] The ADI Combined Index and the Large Cap and Mid Cap Indexes are normally presented with Jan 1950 = 1.00.

[10] Measured trough to trough in constant dollar defense outlays, there are five (four major, one minor) defense expenditure cycles which are present in our data. They are the following: Cold War and Korea 1947–1956 (peak 1953); Missile Gap 1957–1965 (minipeak 1963); Vietnam 1966–1975 (peak 1968); Cold War Finale 1976–1998 (peak 1987); Terrorism, Iraq, Afghanistan 1999–2016? (peak 2011). See Office of the Under Secretary of Defense (Comptroller), 2012, Table 6-11.

Table 1.   ADI Index Composition

	Small Index	Mid Cap Index	Large Cap Index	Foreign Index
Current Market Capitalization (Avg., $ Billion)	1.5	5	35	2.7–27.4
Number of Companies Present Annually (Avg.)	6	27[a]	19	11
Date Range, Years	1998–present	1950–present	1950–present	2000–present
Current Asset Value (Avg., $)	2.2	3.95	32.6	4–111.3
Current Annual Revenue (Avg., $)	1.5	4.5	30	3–61

Notes. Companies in the foreign ADI index span a range of company sizes, all publicly traded and active partners or competitors of U.S. ADI companies.

[a] Most consolidation or movement between size categories in the ADI indices has occurred in the Mid Cap category of companies, where 34 companies formerly in the index are not present in the current index, having grown into a Large Cap company or been acquired by Large Cap company.

NDBI analysis from Google Finance, Bloomberg L.P., and Company Annual Reports.

To ensure representation for the DoD mission, the ADI companies were drawn from the top 10, 25, and 100 defense and space contractors by size of contracts over the last 62 years, from before the Korean conflict to the present. The NDBI sample of publicly traded aerospace and defense companies includes all major industry segments: airframe; engines; missiles and propulsion; ship and ship repair; specialty metals and composites; surveillance, navigation, guidance, electronics, avionics, IT, networks, computing and cyber warfare; radar, sonar, hydrophone, sensors; satellite/space; land vehicles; ordnance; arms; munitions and explosives. About 19 companies have been present throughout; most have undergone one or more significant mergers.

We turn now to analysis using the ADI index series of the problem stated previously: is defense spending a good predictor of the market health—the market valuations—of the ADI companies? And if not, why not?

Analysis of the Data

The plan of analysis is to present a few essential comparisons in visual terms, and then apply quantitative methods to understand underlying relationships in the Structural Modeling section. Figure 1 displays two ADI series (Large Cap and Mid Cap Indexes) with the S&P500 series over the 1950–2011 time period. With all indexes on the same scale, the comparison of relative growth is relatively simple.
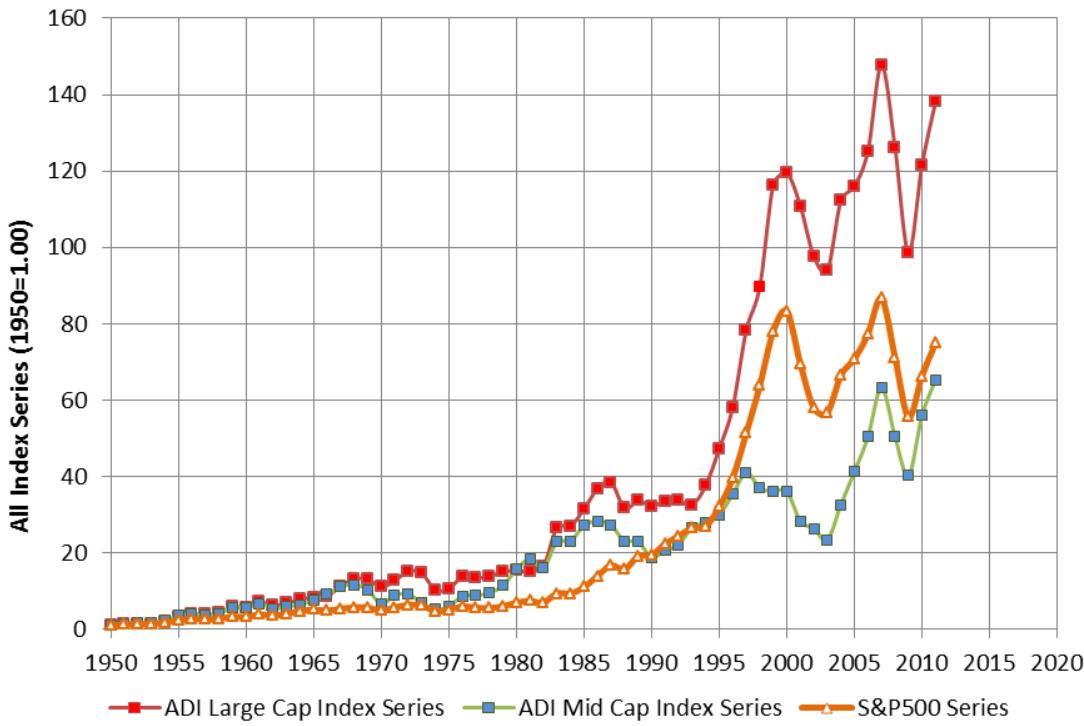
Figure 1.   The ADI Index Series With the S&P500, 1950–2011
Note. The information for this figure was taken from S&P500; ADI Indexes NDBI, from WRDS, Bloomberg L.P. and Google Finance.

The overall perspective is that the Large Cap ADI companies have enjoyed better market health—equity valuations—than the broader industry mix represented in the S&P500 for most of the period. The ADI Mid Cap companies outperformed the S&P500 companies for a portion of that time, but fell behind the S&P500 after 1991. It is also apparent that all three market indexes become more volatile after 1997, with similar timing of turning points in 2000, 2003, 2007, and 2009. The reader might also notice that if we split the graph around year 1995 into two graphs, and fitted a simple trend line through the middle of the series in each half of the graph, the slope of the trend line for the 1950–1994 period would be noticeably flatter than the much steeper slope of a trend line passing through the middle of the series on the right side of the graph for the 1995–2011 time period.

Figure 2 compares the ADI indexes against another key measure of defense industry performance in the U.S. The Federal Reserve Board (FRB), in conjunction with the U.S. Census Bureau, produces an index of defense output (value of production) as one component of its overall FRB Index of Industrial Production.[11] We overlay this FRB Defense Index on the same scale with the ADI Large and Mid Cap Index series. For ease of presentation, we will drop the S&P500 series from this comparison.

Notice the 1990–2000 interval and the behavior of the ADI equity market indexes relative to that of the defense production index. The FRB index falls by 36.45% while the ADI Large Cap Index rises by 270.48% between 1990 and 2000. The ADI Mid Cap Index rises by only 91.34% in the same interval.

Prior to 1990, the FRB index of defense output tracks with the equity performance of the ADI companies reasonably well, as a glance at the 1950–1989 interval should confirm.

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[11] Available online through the St. Louis Federal Reserve Board FRED data system at http://research.stlouisfed.org/fred2/release?rid=13&soid=1 as the G.17. aerospace and defense series.

The situation is quite different after 2000, however, with greater volatility in both the ADI series and the FRB defense index, and only a general tendency in the direction of the upper right of the graph.

One possible explanation is that the 1990s represent a decoupling of ADI corporate equity valuations from their bread and butter business of defense production. The stable relationship that existed prior to the 1990s between defense production and company valuation passes through the disruption of the production–market value relationship of the 1990s only to emerge as a more volatile, and less correlated relationship after 2000.
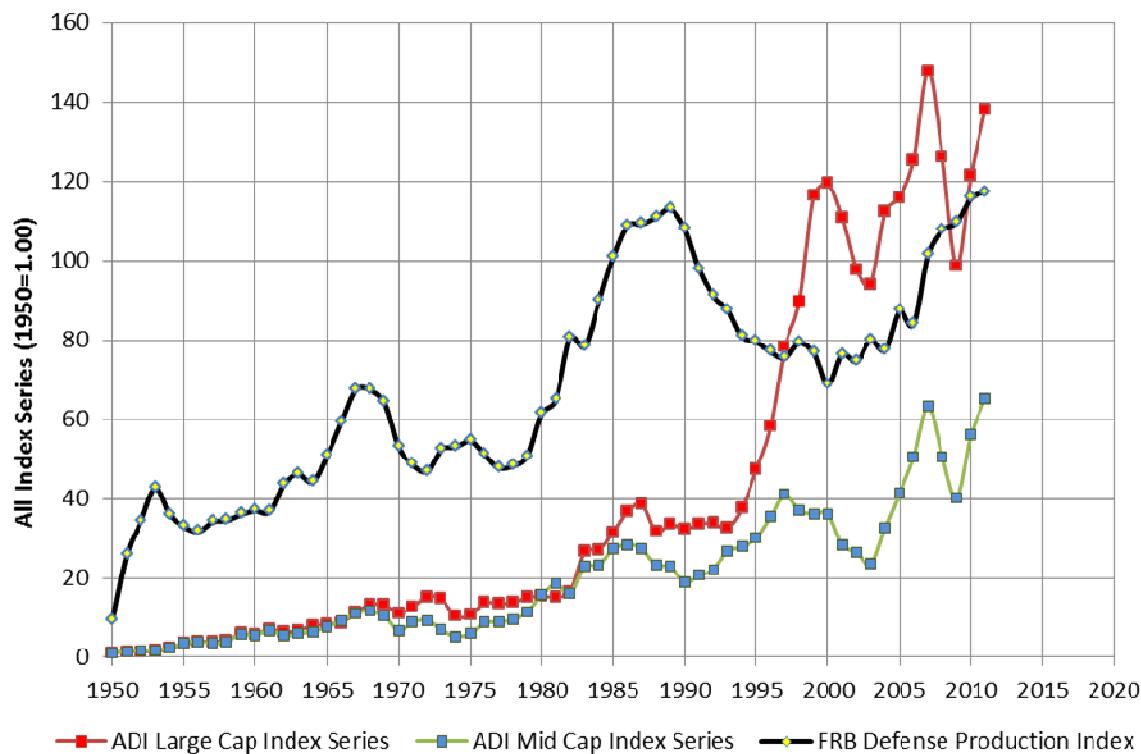

Figure 2.   The Federal Reserve Board Defense Index and the ADI Large and Mid Cap Index Series
Note. The information in this figure was taken from Federal Reserve Board and NDBI.

Figure 3 displays the familiar series on DoD outlays for three component series plus total outlays (Office of the Under Secretary of Defense [Comptroller], 2012, Table 6-11).[12] Outlays are the actual expenditure of defense dollars, and are arguably a superior measure of actual defense spending impact than other series such as budget authority. The series here are the constant dollar series to eliminate inflation as a cause of variation. The Future Year Defense *projections* from the same source for 2012–2016 are provided for each series, shown as the thin sequence of points at the right end of each defense outlay series. Total outlays fluctuate more widely, even in real terms, than the R&D, O&M, and Procurement series, due to several omitted series tracking pay, benefits, and construction, among others. The important point is that R&D, O&M, and Procurement are relatively stable spending series in real terms: whether the statistical correlation with the market health of the ADI companies remains to be seen.

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[12] Also known as the DoD "Green Book," the official title is *National Defense Budget Estimates For FY 2013* (Office of the Under Secretary of Defense [Comptroller], 2012).
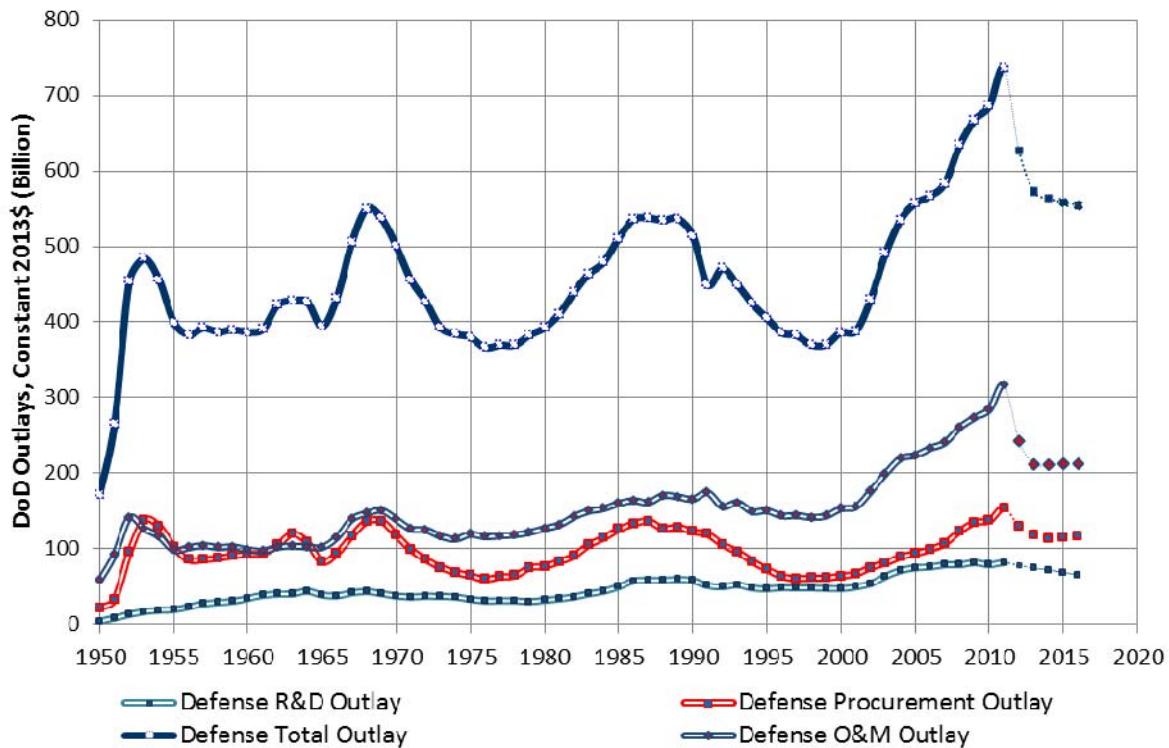
Figure 3. Department of Defense Outlays by Selected Categories, 1950–2011, and Projections, 2012–2016
(Office of the Under Secretary of Defense [Comptroller], 2012, Table 6–11)

Figure 4 overlays the DoD spending series with the ADI Large and Mid Cap market health indexes. The R&D series is dropped for readability.

Note that prior to the early 1990s, the pattern of DoD outlays and the ADI Large and Mid Cap market health indexes track reasonably well. As we saw in Figure 2 with the FRB production index, the relationship between actual defense spending and ADI market health appears as if it was disrupted by events in the 1990s. If there was coincidence between movement of company valuations in equity markets, and patterns of defense spending, it holds reliably only before 1991 or 1992. After that point, equity valuations fluctuated—with wide variance and much inconsistency—only in the general direction of defense spending trends.
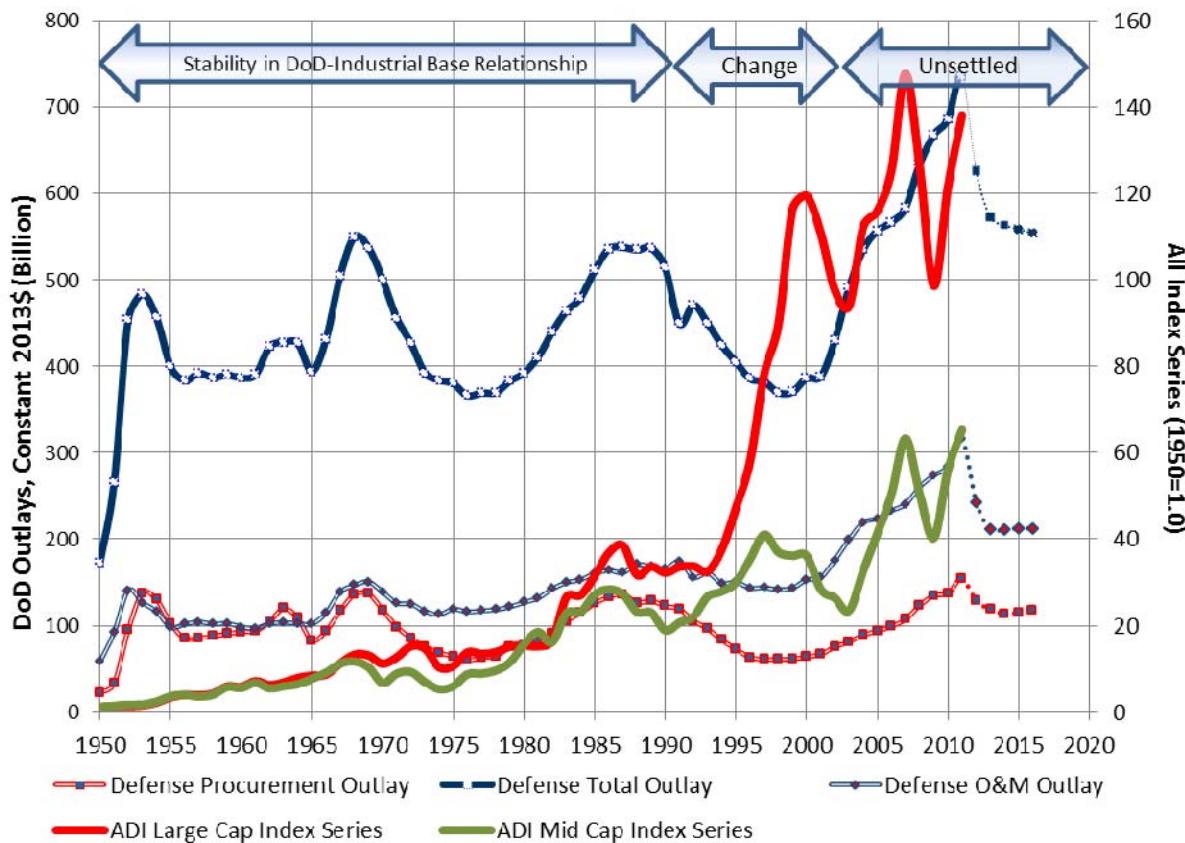
Figure 4. DoD Real Outlays and Long-Term Market Performance of the ADI

Note. The information in this figure was taken from Office of the Under Secretary of Defense (Comptroller), 2012, Table 6–11; Federal Reserve Board; and NDBI.

Figure 4 is labeled with three time periods that are suggested by the graphical analysis of Figure 1–Figure 4. Between 1950 and 1990—four decades coinciding with almost the entire Cold War—there is good visual evidence for a stable correspondence between real defense expenditures and the market health of the ADI companies. Between 1991 and 2003, this comfortable correspondence dissipates with events including pivotal changes in the industrial base within the decade. Coincident with the Second Gulf War in 2003 and continuing to the present time in 2012 (labeled "Unsettled" in Figure 4), there is less correspondence between DoD spending and the equity valuations of the ADI companies, with significant variance and exceptions in 2007 and 2009.

Simply put, the odd decoupling we observed between the well-respected FRB index of defense industrial production and ADI market valuations in the 1990s is repeated here with real defense spending and ADI valuation. Without question, there are implications for statistical modeling when relationships assumed to be predictive suddenly become less so, but there may also be other predictive factors in addition to those presented graphically which could be considered. There is the related question, as a policy matter, how the consolidation of the ADI industrial structure in the 1990s—encouraged at the time by the DoD—may have within a few years increased pricing power and restricted competition so that fluctuations in defense spending were better tolerated. If so, there are lasting implications for DoD concern over weapon system affordability.

Structural Modeling

We turn now to the statistical modeling and analysis of the data set. Structural regression modeling provides a simple way to test if the ideas from our visual inspection of Figure 1–Figure 4 have any statistical validity. The Chow breakpoint test (Intrilligator, 1978, p. 193) indicates that there is a significant structural change in the linkage between market equity valuations and real defense spending centered on 1995, and ADI equity valuations and the FRB defense production index centered on 1998.[13] The exact test results can vary slightly depending on how the models are specified, but the fundamental point is that our visual inspection of a structural change is not mistaken. The testing identifies the preceding two years (1996–1997) and the following year (1999) as part of the same statistically significant period of structural change.

Regression models help to identify the most consistent predictors of the ADI market health measures. Because of the strong time series flavor to the annual series, the regression models require correction for the serial correlation of the errors from one observation to the next. We correct for serial correlation by including the appropriate autoregression (AR) correction as an explanatory variable in the model as well as a moving average term (MA; Kennedy, 2008). The resulting model is a mixed structural model[14] combining the more familiar types of variables created from related data series with time series variables to reflect the strong relationship between the observed value of a series and the preceding and following observed values of the same series.

We also include in these models a number of other variables of interest that predict the value of the target, or dependent variable. One of these is a simple indicator variable to account for the change in the series in the mid-1990s that we spotted in Figure 2, Figure 3, and Figure 4. The cure in our models is to include an explanatory term in model controlling for the influence of unobserved factors not in our model in the time period up to 1995, and in the period from 1995 forward.

A third adjustment is accounting for the systematic effect of trend in several of the series we wish to use to explain the ADI Large Index and ADI Mid Index series over time. A trend adjustment was created using the square root of the basic linear trend value, and produces a significantly improved fit. This is included in both the ADI Large Index model and the ADI Mid Index model.

We turn to the model descriptions in Table 2. We are predicting the ADI Large Cap Index annual value in the first model, and the ADI Mid Cap Index annual value in the second. Several predictor variables are the same in both models, but there are differences as well.

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[13] Using a structural regression model (dependent variable ADI Large Cap Index) estimated with both defense outlays and the FRB production index as regressors for the 1971–1997 interval, and separately using the data for the 1998–2011 interval, the Chow test for structural change easily rejects the null hypothesis of no structural change across the 1971–2011 period with a p-value < 0.000 with 27 degrees of freedom. Clearly there *is* a significant change in the pattern of statistical correlation between predictors such as defense spending and the behavior of ADI Large Cap equity valuation. Similar results occur with structural change testing for the ADI Mid Cap Index model.

[14] Also known as general linear models.

Table 2. Least Squares Regression Models to Predict ADI Large Cap and ADI Mid Cap Index Series

Predictor Variables	ADI Large Index Model β Coefficients (Unstandardized)	ADI Mid Index Model β Coefficients (Unstandardized)
Intercept Constant	-98.45(35.47)**	-42.88(10.13)***
Trend	20.15(7.52) **	11.24(2.12)***
Year 1995 Indicator	29.60(4.81) ***	-
FRB Defense Production Index	-1.80(1.1) *	-
Large Company Order Backlog,$	0.0004(0.0002) **	0.0007(0.0001)***
DoD RD Outlay, $, Year Prior	0.43(0.36)	-0.47(0.2)**
DoD PC Outlay, $, Year Prior	-	0.12(0.05)**
1 Period Autoregressive Term	0.19(0.18)	0.41(0.13)***
1 Period Moving Average Term	0.99(0.11)***	-
4 Period Autoregressive Term	-	-0.57(0.14)***
R-squared	0.97	0.94
Adjusted R-squared	0.96	0.91
Standard Error of regression	8.74	4.39
Sum squared residuals	2518.87	596.65
Log likelihood	-142.59	-106.24
F-statistic	146.87	66.13
Prob(F-statistic)	0.00	0.00
Durbin-Watson stat	2.05	2.06

Note. Dependent variables are the ADI Large Cap and the ADI Mid Cap Index series values in the first and second models, respectively, for the years 1971–2011. The Trend variable is a non-linear square root, instead of linear trend. FRB = Federal Reserve Board; RD = DoD Research and Development defense spending; PC = DoD Procurement spending.

* $p < .10$. ** $p < .05$. *** $p < .001$.

The models in Table 2 are tests of our ability to predict the ADI Large Cap Index series or the ADI Mid Cap Index series using real defense spending and several other explanatory variables as predictors.

The ADI Large Cap Index model uses four variables to produce a more stable prediction—two trend related, and two (the Autoregressive error and Moving Average terms) to account for the error structure of a time series. We can skip over the details to focus

instead on the predictive significance of the FRB defense production index (modestly significant, but negative), the Large Company order backlog (very significant, and positively correlated), and DoD R&D spending from the prior year (a lagged response, not significant). The main problem that the ADI Large Cap Index model has is the explosive growth after the 1990s, for which most explanatory variables we might wish to use, for example, net profit rates, return on shareholder equity, return on investment, and so on, do not correlate well. As we noted from our inspection of Figure 2, the FRB Defense Production Index performs opposite to the ADI Large Cap Index series in the 1990–2000 period, and on other occasions as well in the time since, so that any structural regression model would very likely show the FRB index term with a negative sign—meaning, perversely, that decreases in the FRB defense production index will lead to an increase in the value of the ADI Large Cap Index—which is exactly what we observe for the 1990–2000 period in Figure 2. Overall, with the trend and times series predictors included, the model is stable and performs well predicting using a holdout sample technique.

The ADI Mid Cap Index model uses two autoregressive terms and a single trend term to control as much as possible for the behavior of the index times series and a serially correlated error structure. We can skip over those technical details again and consider the better relationship identified between defense spending and the ADI Mid Cap Index. Specifically, we see that the order backlog of the large cap companies is *highly significant* and of positive sign in predicting the equity valuations of the ADI Mid Cap companies. This is a perfectly plausible result, and a clear acknowledgement of the flow-down relationship between the supplier base and the primes and lead system integrators that depend on them.

The ADI Mid Cap model also has a very significant relationship with two categories of DoD outlays, R&D, and Procurement, both year prior (lagged) values. Only Procurement spending is a positively signed predictor; that is, increases in DoD procurement spending will significantly increase the market valuations of the ADI mid cap companies. Somewhat unexpectedly, R&D spending works in reverse; that is, increases in R&D spending will tend to reduce the value of the ADI Mid Cap Index. Once again, the overall model is stable with the trend and time series predictors included, and performs reasonably well in holdout sample testing.

In summary, it is possible to develop predictive models for the target variables of interest to explain the changes in equity valuation and market health for the ADI Large and Mid Cap companies. The disappointment is that relatively little of the overall predictive power of these models derives from real DoD defense spending on the purchase of materials and services, particularly in the years since 1990. This was not the expected result. The analysis of both models reveals, however, that large company order backlogs *appear to mediate the relationship* with government spending, whether that comes from O&M spending on spare parts or Procurement spending on full rate production. The role of the large company order backlog is highly significant for the ADI Mid Cap company equity valuations, and very important for predicting ADI Large Cap company market health as well.

Discussion

Model tests over earlier periods—before 1990—in the sample produce a better correlation with the categories of defense spending. Model tests including the 1990–2000 period perform less well as predictive models of the ADI health indexes, and it is reasonable to ask why this should be the case. The correct answer to the question posed at the outset in this paper is that defense spending is *sometimes* a good predictor of ADI market health and ADI equity valuations.

It is still unclear why certain defense spending categories should have weak or no correlations at all with one or both of the ADI health indexes in the period since 1990—or for that matter, with the FRB defense production index. Additional work is required to explore alternative model specifications and test different spending categories.

There are also two broad possibilities to consider. One possibility is that aggregated market measures, like stock market indexes, tend to bury the real information at the company level and lose the ability to explain or predict in statistical models. In reply, neither the FRB defense production index nor the ADI indexes maintain a stable statistical relationship with defense outlays in the 1990s—clearly, something changed in the aerospace and defense industry at that time that fundamentally altered the previous rule of thumb that the more defense spending there is, the better the ADI performs. With this research, it appears that at least for the largest ADI companies, at this time there is wider latitude for the present ADI industry structure in responding to defense spending projections than anyone would have imagined 30 years ago. We do not have the answer in this research, but it is likely to be related to the choices made by the remaining five largest U.S. defense companies as the Cold War ended and how the DoD prices and contracts for weapons systems.

Another possibility has to do with the modern longevity of programs, from concept through engineering and manufacturing development (EMD), low rate initial production (LRIP), and so on, to sustainment, coupled with the fact that the largest ADI companies—Lockheed, Boeing, Northrop Grumman, General Dynamics, and Raytheon—have the size now (after the 1990s) to develop and maintain a larger, better diversified portfolio and book of business with a blend of program completion dates for major defense acquisition programs (MDAPs). That diversification could mean that even large swings in spending for several programs could have less effect on their current market valuations than it once did on their predecessor defense companies. Moreover, with the continuing stretch out of MDAPs, a good portfolio of programs could provide adequate revenues and cash flow for decades, something that was far less likely to happen 30 years ago. If this is a reasonable assessment, then we could expect to see an attenuated connection between DoD spending and the market health of the ADI companies—and particularly the largest ADI companies with the most ability to diversify their base of programs and revenue streams.

Conclusion

Before 1990, the market health of the ADI companies was more obviously connected with DoD spending on defense programs. After 1990, this research has identified a disruptive structural change affecting that relationship between 1990 and 2000, perhaps related to fundamental changes in industry structure with the end of the Cold War and the significant consolidation of many previous industry competitors. The current period—post 2000—produces weaker correlation between defense spending and ADI market health, but the counterintuitive patterns of the 1990s relationship between defense spending and ADI market health appear to have passed. The term *unsettled* was used to describe the challenges of forecasting ADI market health at the present time and for the remainder of 2012, while we continue to investigate other possible predictors, market and financial, of the relationship between defense spending and industry health.

As a practical matter, even if the acquisition policies of the recent past seem to have less of an obvious impact on the health of the ADI than it once did, circumstances can change again. Continuing to track the relationship with attention to more detailed spending categories might also refine our understanding of the government–industry relationship and the significant longer-term drivers of industry market performance.

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Acknowledgments

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Aerospace and Defense Industry Market Index for 1950-2012 and the Connection with Defense Spending

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May 2012

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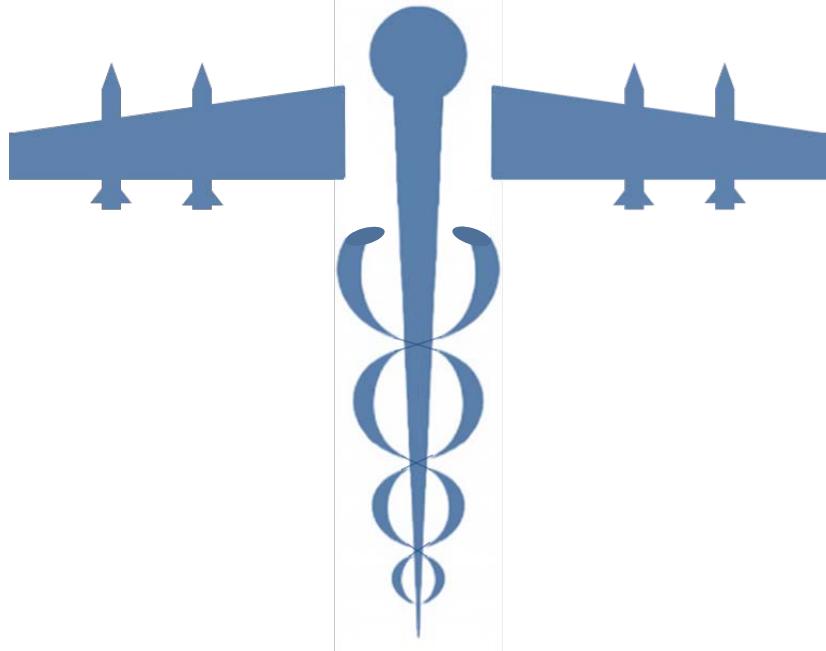
The health of the Aerospace and Defense Industry (ADI) should be assessed regularly to enable government and industry leaders to understand fully how and to what extent changes to its capacities and capabilities can be forecast and thus included in their policy deliberations.

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hypothesis:

Defense spending is a predictor of the equity valuations of the major defense companies.
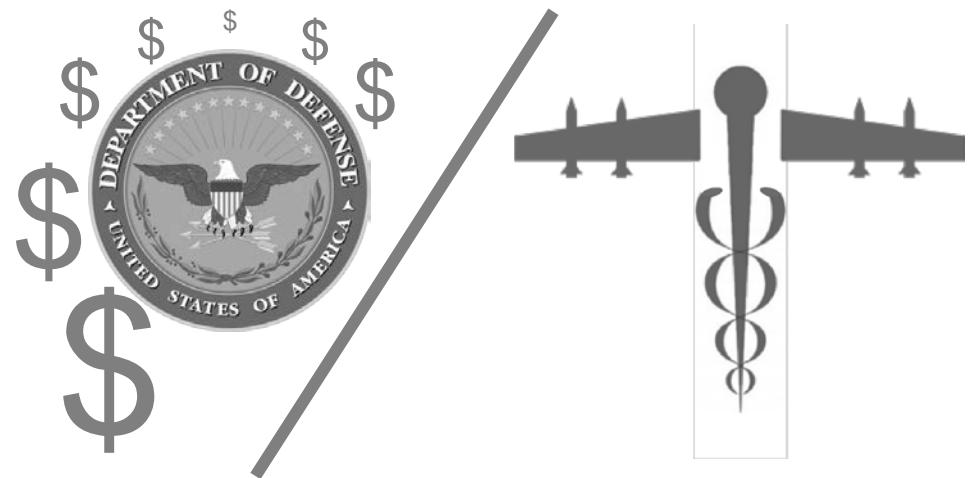
Previous studies have focused on
relatively short time intervals for the ADI…

…too short for understanding long term
trends or forecasting future prospects.

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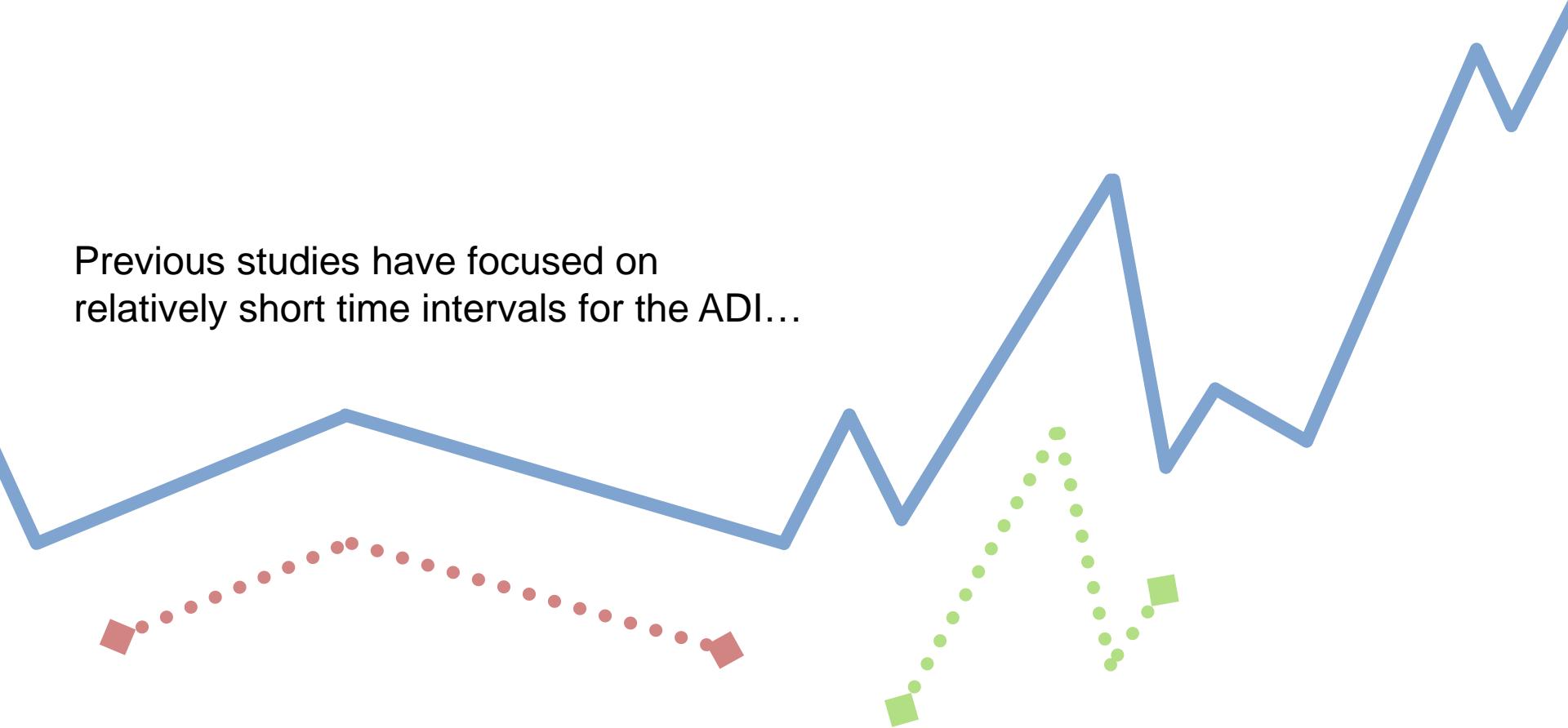
The Aerospace and Defense Health Index (ADI Health Index) is a balanced, share weighted proprietary market index of publicly traded companies, tracking market health from January 1950 to the present.

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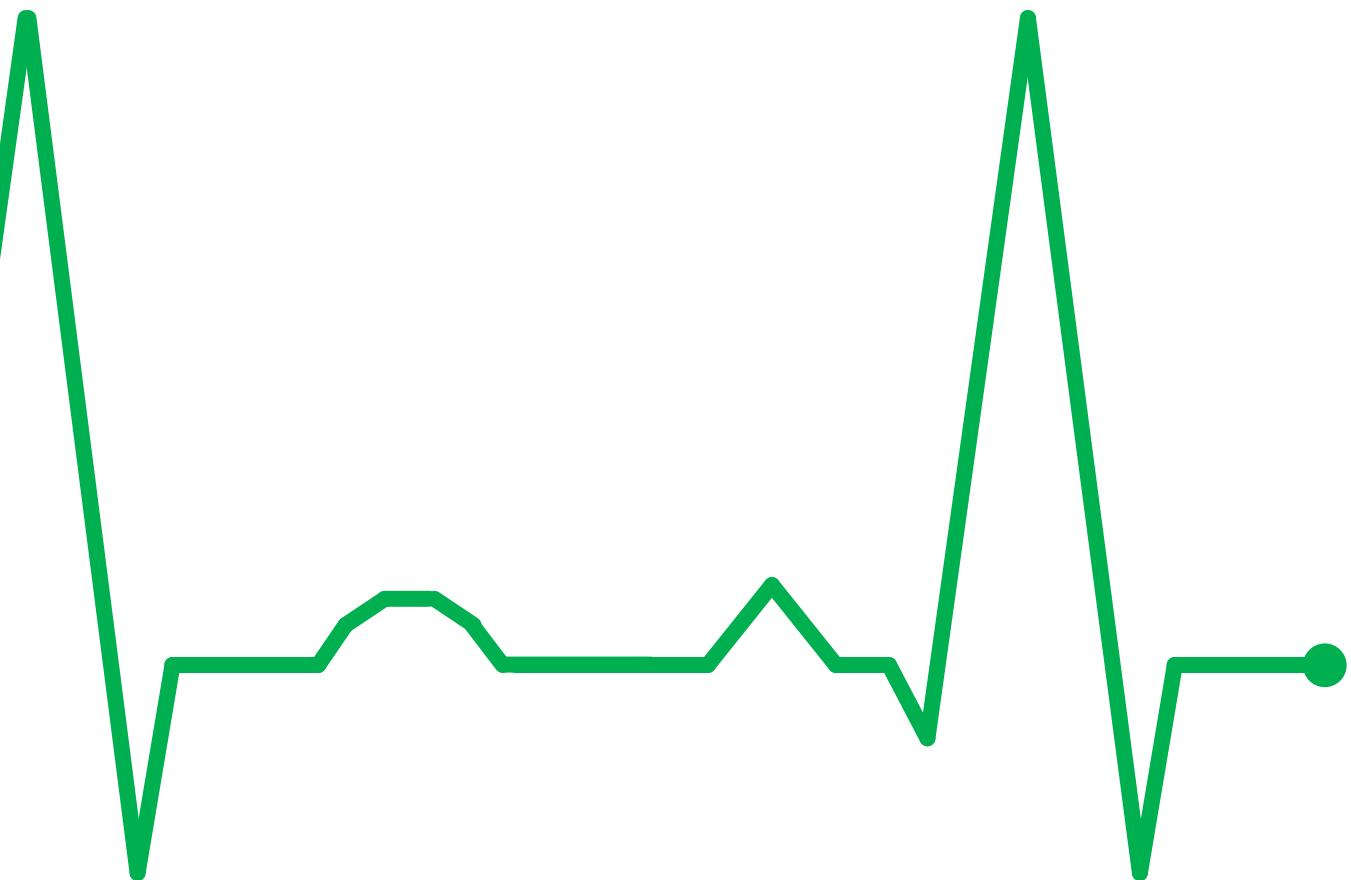
ADI Index Sample

Large Index Companies *
Current Avg. $35 Billion Cap

Foreign Index Companies **
Current Market Cap Range:
$2.7B to $27.4B

Mid Index Companies
Current Avg. $5 Billion Cap

Small Index Companies
Current Avg. $1.5 Billion Cap

	Small Index Companies	Mid Index Companies	Large Index Companies	Foreign Index Companies
Average # of Companies Each Year	6	27	19	11
Date Range	1998-Present	1950-Present	1950-Present	2000-Present
Average Current Asset Value	$2.2B	$3.95B	$32.6B	Range: $4B to $111.3B
Average Current Annual Revenue	$1.5B	$4.5B	$30B	Range: $3B to $61B

* Includes 5 of the "Big 6" – Northrop Grumman, Lockheed Martin Corp., Boeing Co. General Dynamics, and Raytheon
** Includes BAE Systems, the other company in the "Big 6"
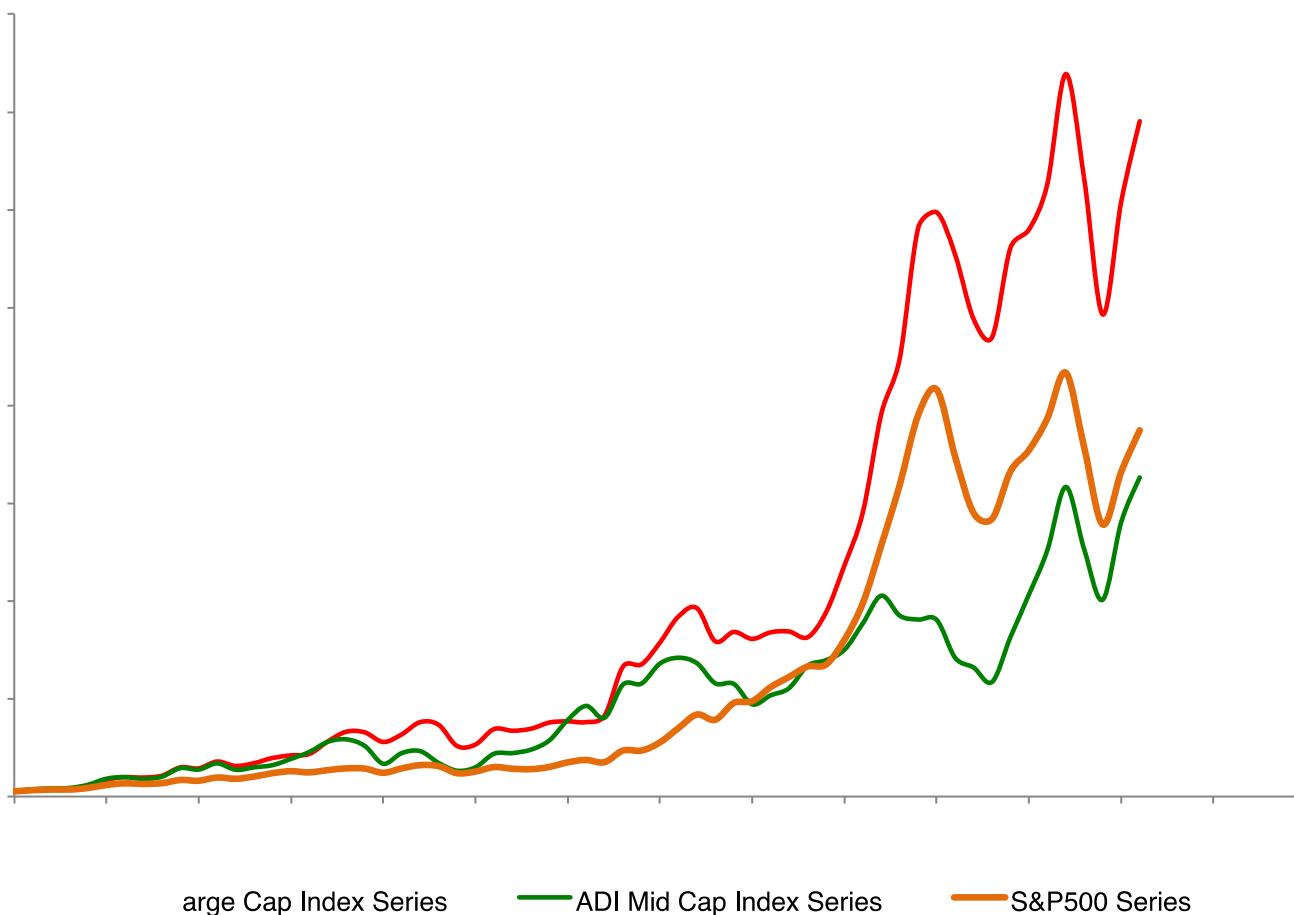
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Figure 1

The ADI Index Series with the S&P500, 1950-2011

Large Cap Index Series — ADI Mid Cap Index Series — S&P500 Series

Figure 2

The Federal Reserve Board Defense Index and the ADI Large and Mid Cap Index Series

Large Cap Index Series | ADI Mid Cap Index Series | FRB Defense Production Index
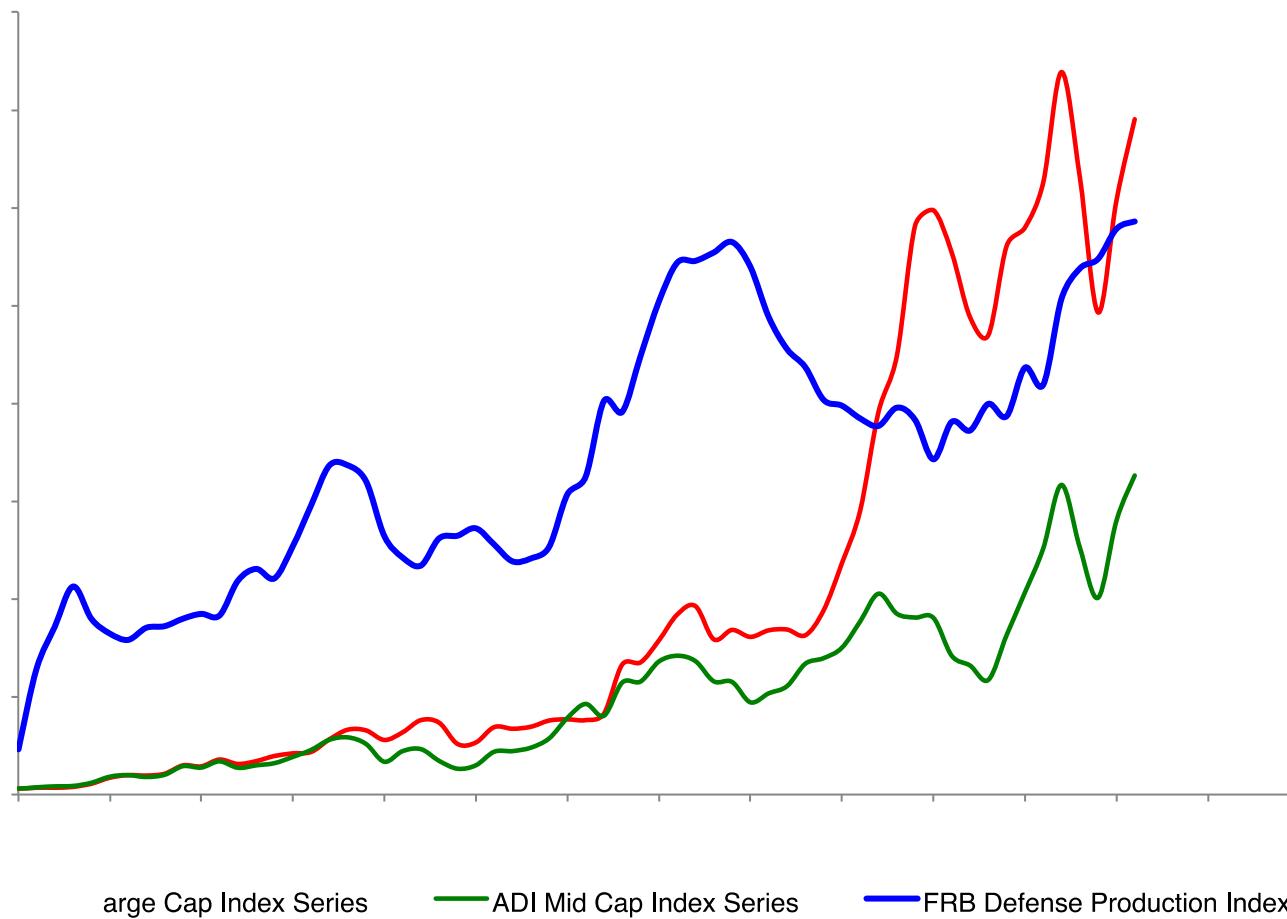
Figure 3

Department of Defense Outlays by Selected Categories, 1950-2011 and Projections 2012-2016
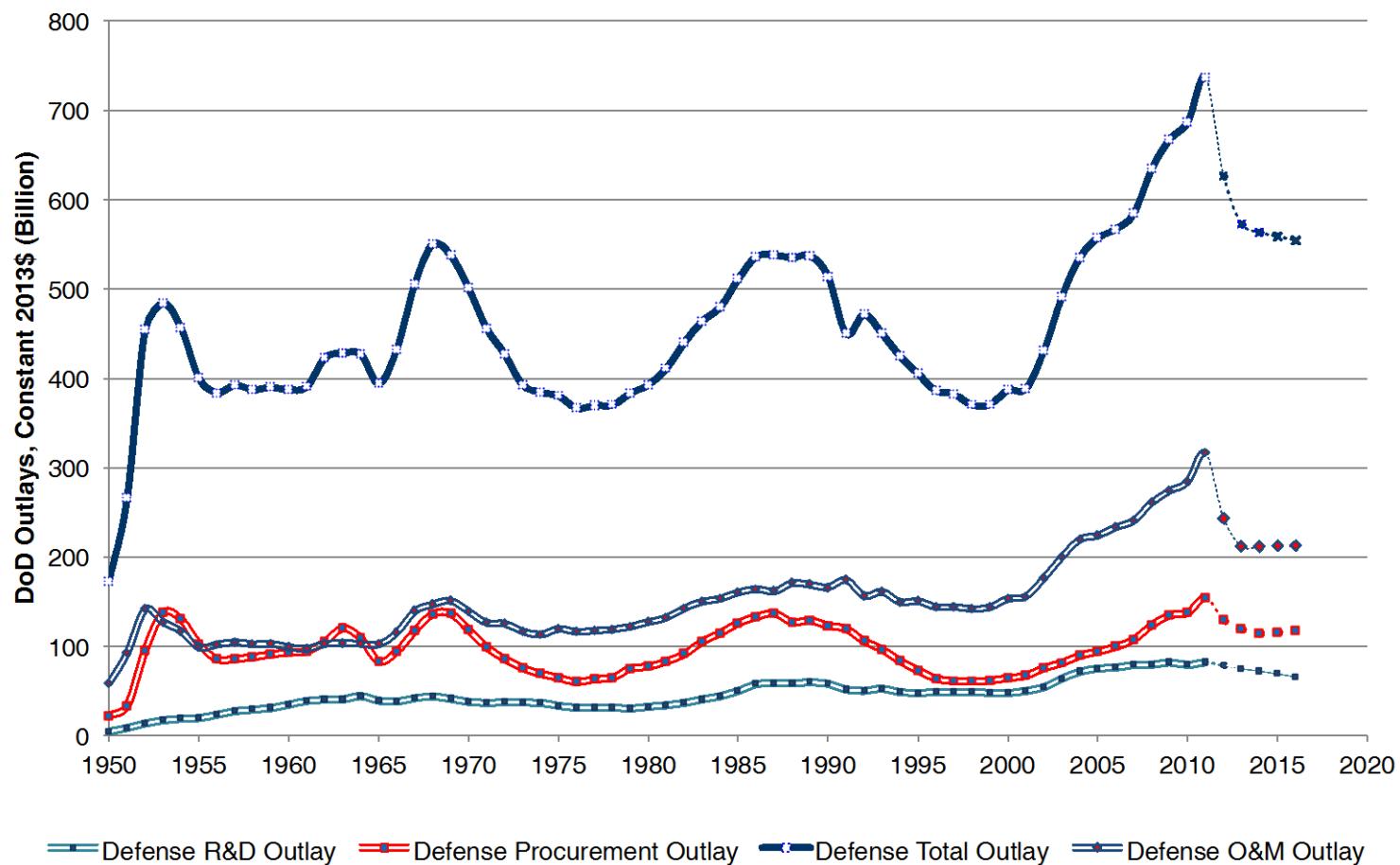
Figure 4
DoD Real Outlays and Long Term Market Performance of the ADI

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Structural Modeling

Predictor Variables	ADI Large Index Model β Coefficients (Unstandardized)	ADI Mid Index Model β Coefficients (Unstandardized)
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4 Period Autoregressive Term	-	-0.57(0.14)***

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conclusion:

Before 1990, the market health of the ADI companies was more obviously connected with DoD spending on defense programs. A disruptive structural change affected that relationship between 1990 and 2000. The current period – post 2000 – produces weaker correlation between defense spending and ADI market health, but the counterintuitive patterns of the 1990s relationship between defense spending and ADI market health appear to have passed.